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Cloud Computing: Business Trends and the Challenges

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Abstract — The purpose of this paper is to provide information to businesses interested in cloud computing. First we define cloud computing and discuss the different service and deployment models from a business standpoint. Then we move into business cases for the cloud and the strengths of each service and deployment model. We follow this up with business attributes that tend to drive a cloud adaption and the effects of cloud on business IT. The last section reveals the challenges of cloud computing ranging from security concerns and legal issues, to negotiation of an adequate service level agreement.

Index Terms – cloud computing, cloud computing effects on business IT, cloud computing challenges

I. Introduction to Cloud Computing

A. Cloud Computing Defined

Cloud Computing is a style (or method) of computing for which scalable and elastic IT capabilities are provided as a service to multiple customers via the Internet [8]. Simply stated, cloud computing enables third party cloud service providers to deliver computing components (such as CPU, disk space, RAM, bandwidth, operating systems, software etc.) as a rentable service rather than as a purchased product. The shared computing resources are provided to users like a utility where the user pays for the utilities used during a certain time period instead of a fixed price.

The fundamental technology of cloud computing is a computer network and virtualization. Virtualization maximizes utilization of the underlying hardware and grants administrators the ability to create additional virtual machines when needed. This elasticity and flexibility is what gives clouds the capability to supply clients with resources as they need them. For the most part, cloud services implement server virtualization (virtual machines or VMs). Server virtualization partitions one physical server/computer into several virtual servers. This allows separate execution on each virtual machine and essentially separates them from the underlying hardware resources. In turn, this maximizes utilization of the underlying hardware and gives the cloud its elasticity and flexibility.

B. Cloud Computing Types

On top of the virtual platform there is a cloud business model and the software which allows implementation of the business model. This business model and the software allow cloud providers to monitor and charge only for resources which are used by their clients. Cloud providers typically break their services into three service models and four deployment models.. There are three types of computing service models: IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and SaaS (Software as a Service); and four main deployment models: public, community, private and hybrid. Each service and deployment model is described in the sub-sections that follow. Table 1 gives a summary of what each service model can provide for businesses.

*1. Cloud Computing Service Models***.** The three types of cloud computing service models are IaaS, PaaS and SaaS. Figure 1 depicts the hierarchal relationship between the various service models and describes the services, hardware and software provided by each [13].

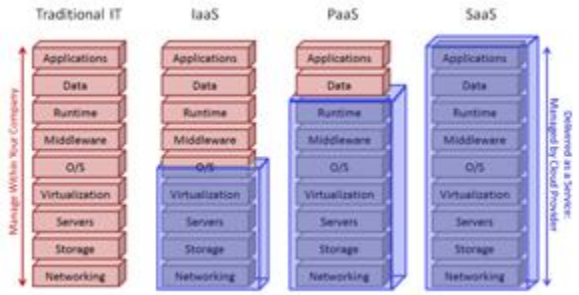

Fig. 1. Cloud Computing hierarchy

Infrastructure as a Service (IaaS) provides underlying hardware and operating system resources. IaaS offers CPU, memory, storage, networking and security as a package [1]. Some current providers of IaaS can be seen in Table 1. For IaaS, a cloud provider offers virtual hosted servers/machines to end-users on a "pay as you go" basis. You only pay for the servers needed to handle the traffic being experienced at that time. It is the IaaS provider's responsibility (such as GoGrid or Joyent) to provide their customers with the correct number of servers, and the correct amount of bandwidth to handle the load.

For instance, during periods of high demand the cloud provider would increase a website's capacity to handle the high-volume traffic. During periods of low demand, the cloud provider would simply scale back the website's capabilities accordingly. The customer benefits by paying only for the resources used. This saves costs for the website owner and is one of the main selling points of cloud computing.Platform as a Service (PaaS) provides a development platform, thus is the service model most commonly used by software developers. A pre-made development platform relocates the upkeep and OS support services from the company to the cloud provider. The software developers would be able to build and test new applications on rented development or production infrastructures with no need to purchase these infrastructures. PaaS provides the customer with the hardware, operating system, software upgrades, security and everything else needed to support the day to day hosting of

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an application [2]. Some examples of PaaS providers are shown in Table I.The cloud service most commonly used is Software as a Service (SaaS). It is currently the most popular type of cloud computing. The first SaaS providers were some of the Application Service Providers (ASPs) which appeared and became popular in the 1990s. SaaS is based on the concept of renting application functionality from a service provider rather than buying, installing and running the software on a personal computer. In theory, any software provided over the internet which has an underlying IaaS/PaaS infrastructure and is provided as a pay-as-you-use service would be classified as a SaaS offering. However, since many internet applications are free along with the fact that it is quite difficult to know on what infrastructure an internet application is running, pretty much any software offered over the Internet which runs remotely is classified as a SaaS offering [3]. The majority of SaaS offerings are either free (email) or subscriptions based, such as online collaboration and CRM (Customer Relationship Management: software applications that allow businesses to manage their relationship with a customer).

2. Cloud Deployment Models. In addition to the three separate service models, there are also four different deployment models: public, community, private and hybrid. Public clouds allow the general public (or a large industry group) access to the cloud infrastructure. The infrastructure itself is owned by the cloud service provider. Public clouds are the least secure of the deployment models but usually come at a lower cost. Community clouds are shared by several organizations and support a specific community that has shared concerns, such as mission, security requirements, policy, or compliance considerations. It may be managed by the organizations themselves or by a third party; and it may exist on-premise or off-premise. Private clouds are constructed for a single organization. It may be managed by the organization or a third party, and again, may exist on-premise or off-premise. Private clouds are typically the most secure deployment models but come at a higher cost. Lastly, hybrid clouds are composed of two or more clouds; such as a private cloud combined with a community or public cloud, but remain unique entities. The security and cost of a hybrid cloud deployment depends on its implementation.

Any of the three service models mentioned in the previous section can be deployed as a public, community, private or hybrid cloud depending on how the cloud infrastructure is set up.

II. Business Cases for Using a Cloud

The following sections outline the advantages of the various cloud types and deployment models based on our research of existing company practices. Table 2 details a compilation of research to determine which cloud service/ deployment model businesses decided to implement based on their individual needs or restrictions. The company information gathered is current as of November 2011. As cloud technology expands in the future, company trends are likely to change.With cloud computing still in its early stages of life, there is a lot of room for improvements and new developments.

A. Deployment Models

Businesses tend to gravitate towards the use of public clouds when growth is dynamic and cyclical. When businesses expect large spikes in their website traffic, or when they are looking for more economical solutions, public clouds are the preferred choice. Of course, when there is no privacy or sensitive data concern, public deployment is a great path to take due to its tendency to be cheaper than private deployment.

Businesses seem more inclined to invest in a private cloud infrastructure when there is a need for high security, custom cloud configurations, or when more frequent interactions with the cloud-provider are desired - for example dealing with company proprietary information. The Cleveland Cavaliers chose to go with a private cloud to ensure one-on-one interaction with their cloud-provider[5]. On the other hand, the Orthopedic Institute decided to take advantage of a private cloud since they must comply with strict Health Insurance Portability and Accountability Act (HIPAA) rules for protecting patient information. Vrooman found that setting up a private cloud would make the most sense for them due to the fact that their website acts mainly as a traffic conduit [5].

When the network handles large amounts of continuous data transfers (terabytes) on a regular basis, a private cloud or no cloud at all might be the best options [4]. When Sony Pictures Image Works looked into cloud computing they came to the conclusion that if they did choose to rent out a cloud, they would need to use a private storage cloud. If they used a public cloud, the network bandwidth they would consume would be tremendous; between the range of 4 and 12 terabytes of data per employee every day. At that time, none of the public cloud providers could supply the company with that level of constant high-demand bandwidth. For this reason Sony Pictures decided to spend more effort on evaluating the possibility of a private storage cloud. [4]

B. Service Models

Our group conducted research to determine when businesses are more likely to rent an IaaS, PaaS or SaaS cloud computing infrastructure. After researching the benefits and downfalls to each infrastructure, the results have been compiled in Table II. The IaaS model is the best choice for legacy systems due to its configurability. Also, businesses with very specific software or OS needs supported by in-house programmers tended to go with IaaS. This allows them to create tailor-made software which is task specific. Also, businesses which see extreme fluctuations in usage seem to slightly prefer IaaS over PaaS. Businesses tend to select PaaS when they are not concerned about the intricate details of the operating system itself and are more concerned about the production of good, reliable software. Removing the burden of infrastructure upkeep and maintenance allows programmers to focus fully on developing new applications. Being able to rent a development/testing or production

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infrastructure gives programmers great flexibility for software development. Businesses tend to use PaaS when the focus of their company is the software they produce and sell to others with a concentration on creating user friendly, multi-use, and multi-platform software.

The SaaS service model is utilized in smaller businesses with a limited budget. SaaS gives businesses the freedom to never worry about security upgrades, software upgrades, hardware upgrades or any other headaches which can arise from having to maintain server and software. There are countless numbers of business tools being offered on the web for a monthly rate, removing the need to ever actually purchase the software or any of the software upgrades and support. In general, SaaS was found to be beneficial for businesses with limited or no IT department where the focus of their business is not computer or programming related. Lawyers, doctors, independent educators, marketing companies, construction businesses as well as many other small business operations all found benefit in taking advantage of SaaS cloud services. That is not to say large businesses could not benefit from using SaaS products, but that most of the time large businesses found the greatest benefit renting IaaS or PaaS. We found that SaaS was utilized by businesses whose main product is neither a software build nor a product dependent on software. SaaS is more commonly utilized as a tool to help with very typical everyday company tasks such as accounting, business, marketing, as well as many others.

C. When Businesses Tend to Stay Away from Clouds

In some scenarios, businesses ended up staying away from cloud computing all together. One of the main situations when cloud computing was not necessary is for very small business websites. Businesses such as GoDaddy, JustHost and MyHosting still hold the market when it comes to web hosting on a small scale. It is hard to compete with the low, fixed monthly rate web hosting these businesses are able to offer. Although it is possible that some web hosting businesses may dip their feet into offering web hosting using a "pay per use" cloud model and cloud hardware infrastructure, it seems somewhat improbable that this path would lead to lower pricing than the prices which already exist at web hosting sites. Another scenario where businesses tend to stay away from cloud computing is when a company works heavily with real-time data. When dealing with critical real-time data where significant latency times are not acceptable (for example in mission critical programs), many businesses decide to stick with the traditional methods of computing. This is one major area in which almost all businesses agree that the cloud is not suited to handle, as of today. One good example of low-latency critical applications can be seen in Wall Street stock companies. Also businesses who have little concern or need to stay current with the newest hardware/software tend to stay away from cloud computing. If all the work can be supported on a five to ten year old refurbished server with no need for the latest software applications, then it is very probable there are few cases which can be made for switching over to cloud services.

III. Adopting Cloud Computing and its Effects on Business IT

Overall our research has lead us to hypothesize that there is no solid formula to determine when a business should or should not adopt cloud computing. However there were several trends that are present among those who did choose the cloud route. Inevitability there are also changes to IT that occur with cloud architecture.

A. Adopting Cloud Computing

Small start-up computing businesses were some of the major users of public cloud computing. The cloud offers a fast, easy, and cost efficient way to setup an IT infrastructure so they could focus on their new business development rather than IT operations. Also since start-ups are highly dynamic, it allows application developers to easily switch development environments or software configurations without huge hassles of purchasing new machines or licenses.

For existing businesses the question of whether to adopt cloud computing becomes complicated. Most advocates of cloud computing support the architecture because of the potential cost savings. The trick is to find out exactly how to achieve those cost savings. Businesses have such a variety of cloud options to choose from (12 different service-deployment model combinations) that it can take a whole separate effort just to figure out what's the best service-deployment model. The driving factors are: what kind of service or data does a business deal with, what are the demands or constraints on this service or data, and what is the current state of their IT infrastructure. These questions are very in-depth on many levels and are not easily answered, especially for the larger well-established businesses.

Those who adopt cloud computing are usually divided into two major groups. Most business either utilized the cloud for: 1. its quantity of cheap storage that can be allocated on the fly, or 2. for its elasticity in resources and computing power. Our research in Table 2 outlines what we consider the major business factors that tend to drive what kind of cloud service-deployment model they adopt.

B. Effects of Cloud Adoption on Business IT

Organizational IT inevitability changes with the adoption of cloud computing. The traditional notion of IT is that they are in charge of setup, maintenance, and configuration of all IT resources. This includes: networks, servers, databases, hardware, operating systems, software, end-user support, etc. With cloud computing, some of these responsibilities are moved to the cloud provider. What specific responsibilities will depend on the chosen service model (IaaS, PaaS, or SaaS). For example with SaaS, the responsibility of software licenses, upgrades, patches, installation and maintenance are all moved from the business IT to the SaaS cloud provider. However, business IT departments may pick up a few new responsibilities such as user support for cloud provider interfacing, or integration with legal. Since the cloud service is dictated by its contract, legal will need to work closely with IT subject matter experts to ensure proper service

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TABLE I. DESCRIPTIONS OF SERVICE MODELS

Description of what each service model provides to the user and real life examples of each type			
	IaaS	**PaaS**	**SaaS**
Provides User/Renter With	[Hardware] - CPU - Memory - Storage - Network - Certain level of Security	[Framework] - Operating system - Middleware - Software upgrades - Certain level of Security	[Applications] - Software (free service to end user much of the time) - Certain level of Security
Maximum needed technical expertise hired by your company	Operating System expertise as well as Developers and software programmers to develop in-house programs/software	Developers and software Programmers to develop in-house programs/software; *OS expertise no longer needed in company*	Business's customers or non-technical employees; much of SaaS is geared towards end users with less technical or IT knowledge.
Benefits for End User	- Ability to scale - relatively low start-up cost - Pay only for what you use - No need to purchase physical data center equipment such as servers because you will be renting the hardware from cloud provider	All the Benefits of IaaS plus … No Purchasing of: - OS - Certain software - Software upgrades - Security *(no need to purchase since are able to just rent)*	All Benefits of PaaS plus … Many customers can share same service (software), but maintain own data securely. Much of the software is free. Software that is not free does not have to be purchased and maintained. You (cloud client) rent the software and the cloud provider maintains the software. No hassle with software installation or upgrades
Flexibility and Control	Maximum flexibility in customization of software and hardware. Better potential for handling traffic spikes and to be capable of configuring hardware/software for maximum utilization.	In between IaaS and PaaS	Minimum flexibility in customization of software and hardware. More generic, already built in capabilities for utilization of hardware and software. Might not be capable of performance which could come from IaaS due to generic configuration.
Real Life Examples	Amazon EC2 Joyent Accelerators GoGrid FlexiScale	Google App Engine SalesForce Aptana Coghead	SalesForce Gmail Zoho Google Apps (not engine) MySpace Flikr Cisco WebEx Yahoo email

is contractually outlined [15].In addition, auditing and tracking tasksmay become a prominent focus for IT. With business operations moving to the cloud, someone must manage what is dynamically created, stored, or used on the cloud. The cloud's ability to quickly allocate or de-allocate resources can become a nightmare for tracking. Some businesses are contractually required to reproduce data when asked, and since the cloud is so dynamic, it can be easy to accidently lose data when a VM gets de-allocated. It could even be possible to lose track of a VM entirely, and it ends up sitting somewhere on the cloud consuming costs and creating a potential security issue.Overall, with the adoption of cloud services we expect to see the IT department headcount decrease in the long run. Short term the IT personnel will be needed to organize the initial hand over, but long term there's less need for large IT departments since much of their responsibilities will migrate to the cloud providers. Thus the open IT job positions will most likely increase for cloud providers, but decrease for individual businesses.

IV. CHALLENGES WITH CLOUD COMPUTING

Although cloud computing can be very attractive in many ways, there are still challenges to keep in mind. The paper presented by Dillion et al [7] describes four main adoption challenges with cloud computing. These are: security, costing model, charging model, and the service level agreement. During our research we also found additional topics for discussion such as interoperability and legal issues. This list outlines some of the main questions for concern and is by no means comprehensive.

A. Security

Cloud computing security is probably one of the most important subjects to consider when deciding to utilize cloud computing. The fact is, data is stored on someone else's hardware, and that can be a serious risk if the data is highly sensitive. There could be issues of privacy, data loss, and even the physical security of the device. In addition, since cloud computing specializes in sharing resources, there could

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be a chance business may be sharing the same physical machine with other, perhaps malicious, users. This brings to attention the topic of "reputation fate sharing", where your reputation is shared by the fate of all others also sharing the same physical resource [7]. Also, some may argue the fact that since the data is distributed across multiple locations (internally, and remotely on the cloud, which itself may include several locations), there are that many more opportunities and outlets for hackers to attack [9]. Instead of a single point of entry, the distribution has now created numerous points of entry, which all need to be secured and controlled. For data confidentiality, encryption has been suggested as a partial solution. An example would be to have the data encrypted locally before being stored on the cloud [9]. This, of course, creates more resource overhead.

B. Costing Model

Another hurdle with cloud computing is a costing model. While using cloud computing can reduce costs spent on servers and hardware, there can be additional unforeseen costs to consider. For one, the cost of data communication may increase [7]. Data transfer rates can increase depending on the cloud set-up and the type of data being transferred. This is especially true during the adoption period when a business initially moves their data to the cloud. Businesses that implement encryption security measures also have to consider the extra bandwidth required to transfer encrypted data and keys. Also, the processing power needed to constantly encrypt and decrypt data to and from the cloud would also cost resources.

Additionally there is the cost of integrating company workstations to communicate with the cloud. Each cloud has its own interface and protocols for communication, thus the business will have to install the necessary software to interact with the cloud resources. This could range from a simple FTP program or web browser to custom licensed software. If a business is using multiple cloud computing providers, each provider may require unique software to interface with their system. This brings a new issue of interoperability into play, which will be addressed in detail later.

C. Charging Model

Developing a reasonable charging model can also be a challenge for inexperienced cloud users. A charging model is basically the contract you sign with the cloud provider which outlines charges for different services. A consumer of cloud computing should fully understand the charging model offered by the provider. It should incorporate all the dynamic usage of the cloud's resources. The type of resource will vary depending on the cloud computing service model, but some examples are: network usage, software licenses, data storage, etc. [7].The charging model should also be customized to accommodate only the resources a business needs. This is,of course, one of the great benefits of using cloud architecture. Ideally a business should know exactly what kind of cloud service they need. This not only includes the amount of storage and servers needed, but qualities like robustness, security and integrity. Also note some qualities may not be as important as others. Say a business wants to use cloud services for storing a back-up copy of a trivial informational database. An example of trivial data would be product lists with descriptions, pricing, and other information readily known to the public. In this situation, the business would be focused on ensuring data integrity (having the data accurate and trusted), rather than data confidentiality (only authorized users have access).

Thus the business may not require a high level authentication and authorization security protocols that for example a sensitive financial business might need. This level of customization might not be available by all providers, which is why it is important to sit down with the cloud provider and discuss available customization options before jumping into any final agreements [6]. Along the lines of a charging model, businesses may also want to look at what kinds of cost monitoring tools cloud providers offer, if any. Businesses may need to closely monitor what's being charged to their account not only for auditing purposes, but also to avoid end of the month billing surprises. For example, a developer at InformationWeek.com accidently left a resource hungry application running on their rented Amazon Web Services cloud. No one noticed until the bill went up tenfold at the end of the month [14].

D. Service Level Agreement

The service level agreement (SLA) is the contract signed by both provider and consumer that guarantees aspects such as quality, availability, reliability and performance of resources [7]. This contract is especially important to a business, and the legality of drafting up such a document can be difficult. The SLA must be specific enough to cover the consumer's expectations but drafted in such a way for the components be measureable and verifiable. Since the SLA covers non-technical aspects this may be challenging, but for businesses that deal with critical data, any downtime or outage could present serious obstacles and needs to be addressed. Thus businesses should also be sure to include scenarios in which they have the right to terminate the contract. For example, if a cloud provider consistently goes down or offline, businesses should be able to cancel their contract instead of being locked in until the end of the year. On that note, any issues caused by unpredictable environmental disasters (power outages, hurricanes, etc) also need to be clearly outlined in the contract [6].

E. Interoperability

There may be a time when a business might consider using multiple cloud computing providers. Reasons for this may be security (don't put all your eggs in one basket) or just the scope of a provider. For example, as a business you may want to divide or replicate your sensitive data onto multiple clouds in case one was to fault or malfunction. Another example is a cloud provider that specializes in certain software as a service, but does not have adequate infra-

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TABLE II. COMPANY TENDENCIES ON DEPLOYMENT MODELS AND SERVICE MODELS FOR CERTAIN ATTRIBUTES THAT A COMPANY MAY HAVE

Company Attribute		Public	Private	IaaS	PaaS	SaaS
Size	Large company (>35 Million) (> 500 Employees)		□	□	□	□
	Mid-sized businesses (> $7 Million) (100-500 Employees)	□		✓	□	□
	Small businesses (< $7 Million) (< 100 Employees)	□			✓	□
	Very small companies (< $500,000) (1 to 10 Employees)	□				□
Legacy & Pre-existence	Already have a pre-existing datacenter (multiple servers owned)	□	□	1	2	
	Legacy systems and systems using old hardware/software	2	1	□		
Data Sensitivity	Sensitive client data		□	□	□	
	Company proprietary data		□	□	□	
Speed & Flexibility	Best for transactions which cannot accept latency in system			□ *if any*		
	Best for extreme fluctuations in traffic	1	2	1	2	3
	Meet needs of a fast growing business	1	2	1	2	3
Low Budget	Generally the lowest cost option for big business (>1Billion)	□	□	□	□	
	Generally the lowest cost option for small business (~500 Million or less)	□				□

Table Key
✓ = Is acceptable for this need. The best fit for what is being stated
1-3 = Ranking of most commonly used (1) to least commonly used (3) for the described system/scenario

structure to store large databases. Thus a business may need to enlist the help of a different cloud provider in order to host their databases. Whatever the reason for using multiple cloud providers, a business needs to be aware of the interoperability issues that come with multiple clouds.

As cloud computing is still relatively new, there has not been much development in the way of standardized interfaces and protocols. Cloud provider may have different techniques for interfacing with their clouds. Because of this, businesses that utilize multiple clouds will have to integrate each provider's unique interface into their work station. This could be costly depending on how complex the integration is, and how many workstations need to be integrated [7]. There is also the issue of portability when moving applications/data between clouds. Applications developed on one SaaS cloud provider may have custom configurations and tracking/ debugging data that may not be easily moved to a different SaaS provider [14]. Fortunately, organizations such as the

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Open Cloud Computing Interface [10] and the Open Data Center Alliance [11] have been diligently working to develop standardizations. In the future this may be less of a problem, but as for now it is something to consider when using cloud computing [7].

Touching back on security, there's also the likelihood that each cloud provider has its own pre-defined levels of security, each uniquely implemented. Therefore, when using multiple cloud providers it's critical to be aware of the differences in their security policies. When specifying "data confidentiality" to one provider, they may give you 128-bit encryption, multiple authorization mechanisms, and permission control. But with another provider they may only do 64-bit encryption, two authorization mechanisms, and minimal permission control. The ultimate goal is to have all data residing at the same level of security assurance [12], which is not always easy to achieve when working with multiple parties.

F. Legal Issues

In addition to the above issues, there is another challenge presented by Lehman, et al [14]. Lehman brings attention to the legal issues with cloud computing. This mainly concerns businesses who utilize clouds in the public domain. To start, just data tracking and auditing within a cloud can be difficult. Businesses dealing with financial data are required to keep an audit trail [14]. With the data being located on a cloud service, businesses have to ensure the provider can offer sufficient tracking and auditing features to the level their policies dictate [22]. Secondly there's the issue of subcontracting. Some cloud providers may subcontract portions of their operations to other businesses. If a consumer plans to store sensitive or government data on the cloud, they would need to be legally notified of any sub-contractors. Although this breaks the transparency of cloud computing, it is important enough to warrant exposure. The customer also needs to understand cloud provider bankruptcy. There must be a clear understanding of what happens to the data should the cloud provider go bankrupt or become acquired by another company. Questions such as "what happens to the data legally?" and "is the data returned back to the customer?" need to be addressed before committing to a provider [22]. Lastly, there is the issue of data jurisdiction. If a business stores data on the cloud, the physical location of the data could fall within a different legal jurisdiction than the actual company. This is especially the case when cloud computing expands to a global scale. International cooperation would be needed to dictate between jurisdictions. In general, when using cloud resources, a business should be aware of the legal issues that come with crossing jurisdiction boundaries [14].

Conclusion

Cloud computing provides various deployment methods and service styles which can be implemented in a variety of combinations. Each combination has unique benefits and advantages. Deciding on a type and how to utilize the cloud technology can be a difficult process for some businesses. Implementing a cloud type unsuitable for a company could lead to increased company costs; whereas finding just the right fit could significantly decrease costs and relieve the company of some of the day to day headaches of server upkeep. We've assembled all our research into this one document with the main goal of helping businesses understand the world of cloud computing which they could then use to determine what cloud model would work best for their company. However keep in mind that despite the advantages of cloud computing, there are still several challenges that should be considered. These are, but not limited to: security, costing model, charging model, service level agreement, interoperability, and legal issues. Even businesses that are not interested in transferring to a cloud based computing system can still benefit from understanding the wide expanse it covers. Cloud computing continues to evolve and its use stretches to every corner of the Internet. Gradually it is changing the world of computing as we know it today.

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